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Effects of Crystallographic Orientation on Tensile Deformation in the Excess-Mg Type Al-Mg-Si Alloys

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Heat-treatable 6000-series alloys are currently used in automotive body sheets for reducing the weight of automobiles. It is popular that the addition of other elements in Al-Mg-Si alloys will improve mechanical properties. Hardness measurement, tensile test, and SEM observation have been performed in order to understand the relationship between tensile deformation and crystallographic orientation of grains in the excess-Mg type Al-Mg-Si alloys. The electron backscattered diffraction (EBSD) technique has been performed in order to analyse individual crystallographic orientation in these alloys. Al-1.0mass%Mg_2Si-0.4mass%Mg(ex.Mg alloy) and Al-1.0mass%Mg_2Si-0.4mass% Mg-0.5mass%Ag (ex.Mg-Ag alloy) were used for this work. In ex.Mg-Ag alloy, 0.2% proof stress and ultimate tensile strength (UTS) were higher than ex. Mg alloy. The Schmid factor (S.F.) of individual crystal grains and stress transmission factor (Nij) were calculated by crystallographic orientation from EBSD. After the additional deformation to UTS for ex. Mg alloy, initial crack was observed at the grain boundary between higher S.F. and lower S.F. grains and Nij is low. Meanwhile initial crack in case of ex. Mg-Ag alloy was observed at the grain boundary between lower S.F. and lower S.F. grains and Nij is low.

Keywords: *Al-Mg-Si, elongation, EBSD, orientation, SEM*

1. Introduction

Recently, the light weighting of the vehicles application of the 6000 series Al-Mg-Si alloy for body sheets of vehicles are advancing for reduction of environmental impact[1]. Thermo-mechanical treatment has been performed to improve mechanical properties of 6000 series Al-Mg-Si alloys. The peak aged 6000 series Al-Mg-Si alloys will cause intergranular fracture, and their ductility and fracture toughness will decreased. Three methods are usually taken for the improvement of the mechanical properties: ①increase of Mg and, Si [2], ②addition of transition metals for grain refinement [3], [4], and ③heat-treatment [5]. We have reported the relationship between tensile strength, deformation and crystallographic orientation of Al - 1.0 mass%Mg_2Si alloy(Base alloy) and Al - 1.0 mass%Mg_2Si - 0.4 mass%Si alloy (ex-Si alloy) by electronic backscattering diffraction (EBSD) technique. After the additional deformation up to the ultimate tensile strength (UTS) of Base alloy, the cracks were observed at grain boundaries that has a larger difference with Schmidt factor (S.F.) between crystal grains and smaller difference with stress transmission factor (Nij). These cracks were classified to Type B of Table 1 [6]. It was reported that ex-Mg alloy would result in fine ductility. The relationship between crystallographic and tensile deformation, however, was not been reported yet.

In this study, hardness test, tensile test and EBSD have been performed for peak-aged ex.Mg alloy and the ex.Mg alloy with Ag addition to understand the relationship between crystallographic orientation and good elongation. And the peak-aged ex.Si alloy is taken for comparation.

2. Experimental

ex.Mg alloy and ex.Mg - Ag alloy were prepared by high purity Al, Mg, Si. Sheets of 1 mm thick were made by hot- and cold-rolling, followed by solution heat treatment at 848K for 3.6ks and quenched into chilled water. Quenched sheets were aged at 423K in oil bath. The micro-vickers hardness was measured with AKASHI MVK-E II (load: 0.98N, holding time 15s). Tensile specimens were cross-section of 0.8mm×5.8mm and gauge length of 17.5mm. Tensile tests were performed at room temperature and strain rate was 1.0×10^{-3} s^{-1}. Fracture morphologies and crystallographic orientation were observed on the optical microscope (OM) and SEM (Hitachi S-3500 and OXFORD Opal).

3. Result and discussions

Figure 1 shows age-hardening curves of three alloys aged at 423K. Hardness was increased and the time to the maximum hardness shortened for the alloy with the ex.Si. Figure 2 shows the nominal stress-strain curves of three peak aged alloys for each alloys. 0.2% proof stress and UTS of the ex.Si alloy were higher than those of ex.Mg and ex.Mg-Ag alloys. Elongation to failure and uniform elongation were increased for ex.Mg and ex.Mg-Ag alloys. Figure 3 shows SEM images of fracture surface obtained for every alloy. The ex.Si alloy showed mainly intergranular fracture, while, ex.Mg and ex.Mg-Ag alloys showed transgranular fracture. Figure 4 shows the SEM images of these alloys after UTS. Slip bands can be seen at a locally the surface in the ex. Si alloy. The ex.Mg alloy was deformed widely and the surface was rough. S.F. of individual crystal grains and Nij were calculated by crystallographic orientation from EBSD. Figure 5 shows the SEM images of expunding from Fig 4.White and black circles exhibit for higher S.F. and lower S.F. grains, respectively. White line stands for fractured grain boundaries and decides with the number.After the additional deformation to UTS for ex. Mg alloy, initial crack was observed at the grain boundary between higher S.F. and lower S.F. grains and Nij is low. Meanwhile initial crack in case of ex. Mg-Ag alloy was observed at the grain boundary between lower S.F. and lower S.F. grains and Nij is low. Figure 6 shows SEM image of the initial crack in ex.Mg and ex.Mg-Ag alloys. A yellow line shows fractured grain boundaries. The grain boundary where the crack was observed was classified as the Type D. This means that the grain boundary between grains with higher S.F. was fractured initially.

4. Summary

As a result of EBSD maps, it was thought that tensile deformation depended on crystallographic orientation of grains:

1) Ex.Si alloy: Initial crack could not observed in UTS because of brittleness. All fractured grain boundaries were mainly classified with the Type D.

2) Ex.Mg and ex.Mg-Ag alloys: Initial crack were observed at grain boundaries in Type D. All fractured grain boundaries were classified with Types B, C and D.

5. Referrence

[1] The Japan Inst. Light Metals：Manufacturing technique for car lightweighting,
Nikkan Kogyo Shimbun ltd.(2003),9.

[2] Oohori,K:The microstructure and property of Aluminum:The Japan Inst. Light Metals (1991),278.

[3] Baba,Y.,Takashima,A.: J. Japan Inst. Light Metals ,19 (1969),90.

[4] Yokota,K.,Komatsubara,T.,Sato,T.,Kamio,A.,: The Japan Inst. Light Metals ,42 (1992),149.

[5] Ikeno,S., Kakuthi,S.,Mae,T.,Tada,S.: The Japan Inst. Light Metals,33 (1983),3.

[6] Matsuda,K.,Tsukiyama,J.,Uetani,Y.,Ikeno,S.: The Japan Inst. Light Metals ,58 (2008),388-394.

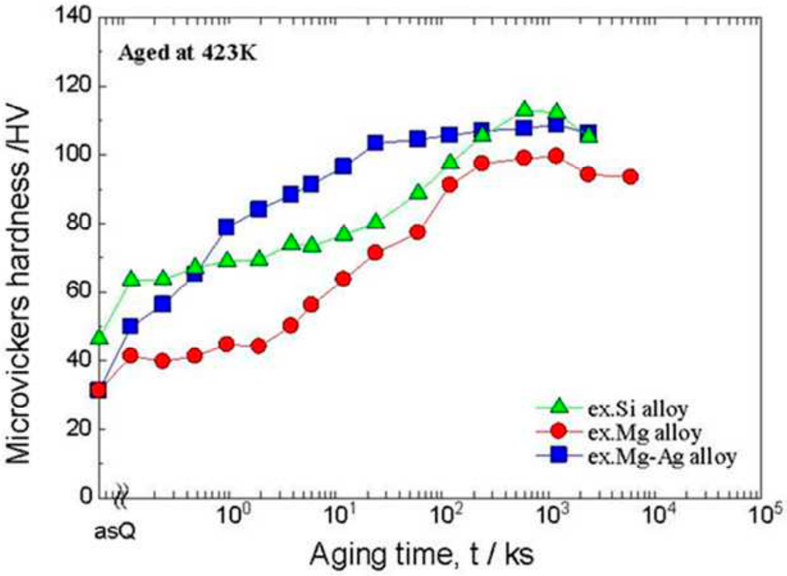

Fig. 1 Result of age-hardening curves

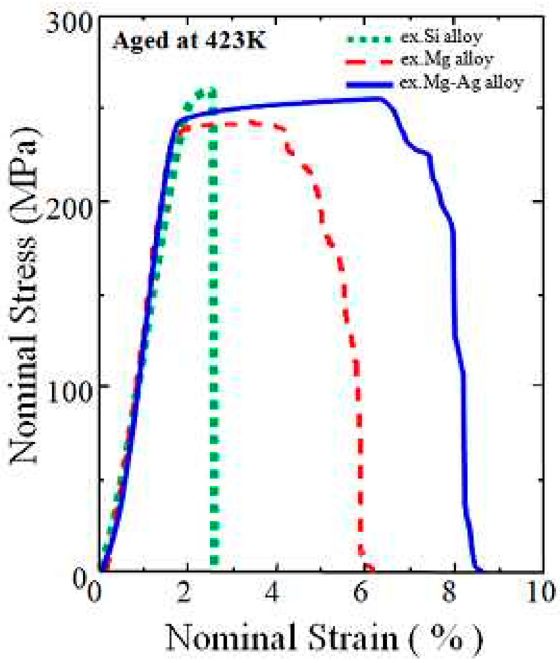

Fig. 2 Result of tensile test

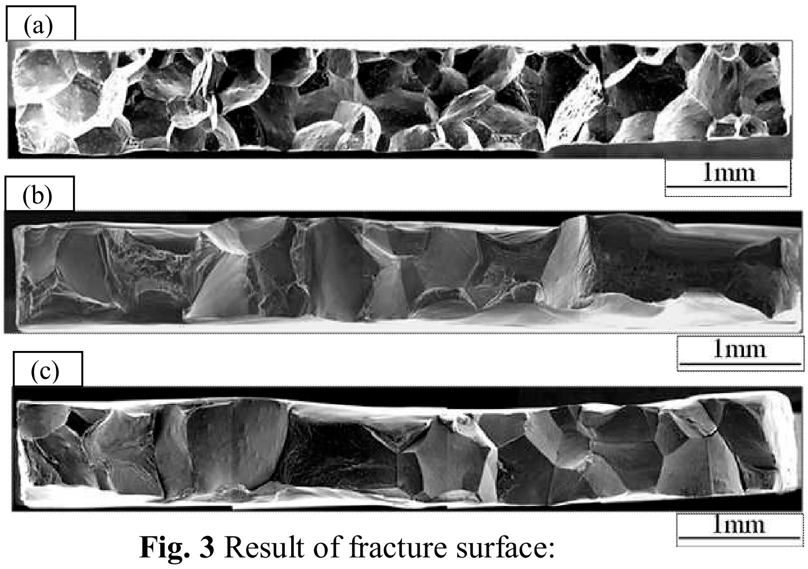

Fig. 3 Result of fracture surface:
(a)ex.Si alloy,(b)ex.Mg alloy,(c)ex.Mg-Ag alloy

Table 1:Types of grain boundary between the neighboring grains.

Types of grain boundary between the neighboring grains
・Type A has larger difference in S.F. and higher transmission factor (Nij).
・Type B has larger difference in S.F. and lower transmission factor.
・Type C has smaller difference in S.F. and higher transmission factor.
・Type D has smaller difference in S.F. and lower transmission factor.

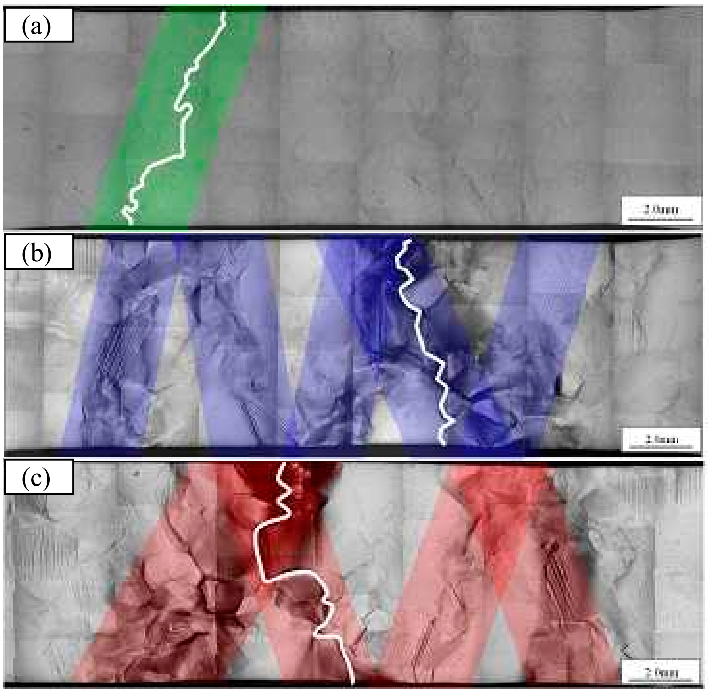

Fig. 4 Optical micrographs of specimen surfaces with ultimate tensile strength: (a)ex.Si alloy,(b)ex.Mg alloy,(c)ex.Mg-Ag alloy

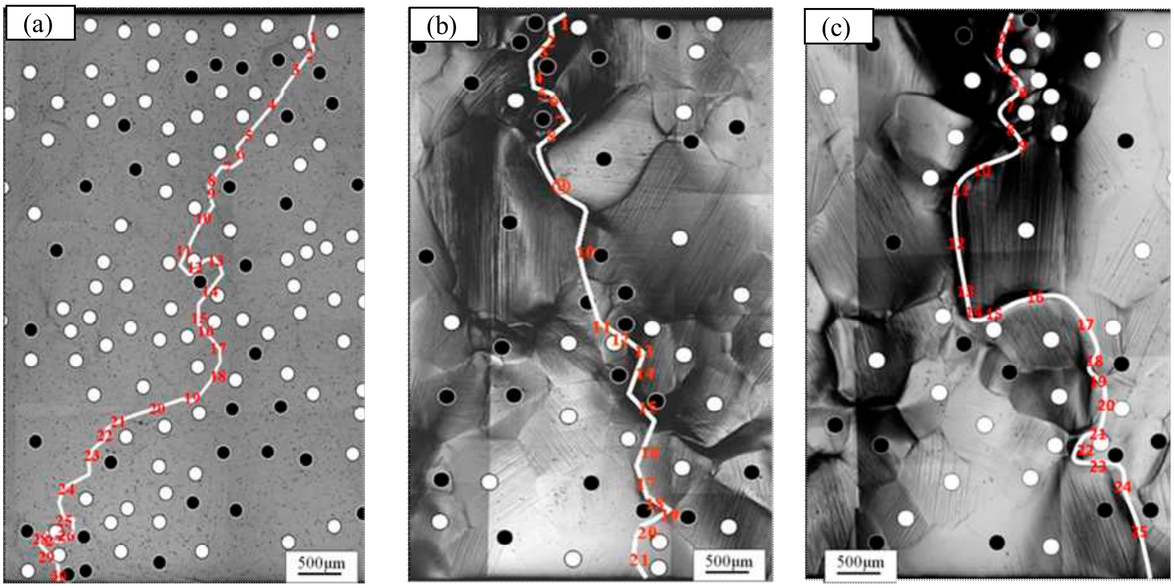

Fig. 5 Fractured grain boundaries and S.F. near grains: (a)ex.Si alloy,(b)ex.Mg alloy,(c)ex.Mg-Ag alloy

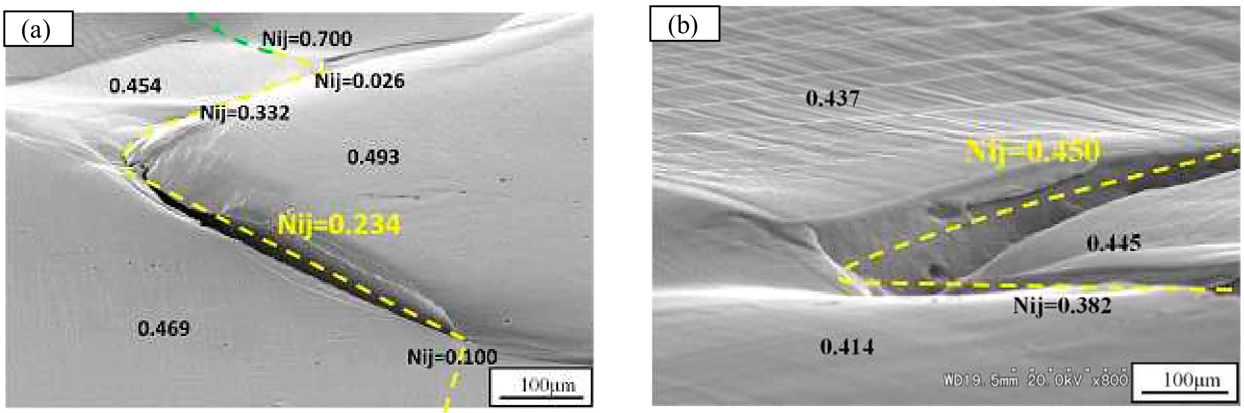

Fig. 6 SEM image of initial crack: (a)ex.Mg alloy (b)ex.Mg-Ag